solder bumps that are reflown into solder balls with a larger height and a larger pitch between the balls.

[0017] Several other methods are known to those skilled in the art for producing solder bumps on a semiconductor device. One such method is called the solder jet printing method. The solder jet printer method is based upon piezoelectric demand mode ink jet printing technology and is capable of producing and placing molten solder droplets 25-125 micrometers in diameter at rates of up to 2000 per second. In demand mode ink jet printing systems, a volumetric change in the fluid is induced either by the displacement of piezoelectric material that is coupled to the fluid or by the formation of the vapor bubble in the ink caused by heating a resistive element. The volumetric change causes pressure transience to occur in the fluid, and these are directed so as to produce a drop that issues from an orifice. A droplet is created only when it is desired in demand mode systems. Demand mode ink jet printing produces droplets that are approximately equal to the orifice diameter of the droplet generator.

[0018] Another method for producing solder bumps is known as the micro-punching method. In the micro-punching method, solder tape is supplied from a spool and rolled up by a motor driven spool. A micro-punch is driven by an electric actuator and a displacement enlarging mechanism. A micro-punch and die set blanks a thin solder tape and forms a small cylindrical piece. A solder flux may be formed over the entire semiconductor wafer to be bumped and the solder pieces may be punched and placed directly onto the wafer.

[0019] Figs. 1A-G illustrate the various steps of a prior art method of forming a bump on

a wafer or flip chip. Fig. 1A shows a semiconductor wafer 10 having a passivation layer 12 as on upper surface thereof. An opening 14 is formed in the passivation layer 12 down to a contact pad 16 of the semiconductor wafer 10. The semiconductor wafer upper surface is sputter cleaned to remove any oxide that may be present on the upper surface of the contact pad 16. As shown in Fig. 1B, thereafter an under bump metallurgy (UBM) 18 is deposited over the entire wafer by any of a variety of methods but preferably by sputtering. The UBM 18 may be made from any of a variety of metals, for example, layers of copper and titanium. Thereafter, a photoresist layer 20 is deposited over the wafer, developed and patterned to provide an opening 22 overlying the contact pad 16 (Fig. 1C) . As shown in Fig. 1D, solder 24 is electroplated into the opening 22 and onto the UBM 18 overlying the contact pad 16. Thereafter, layers of copper and nickel 26 are electroplated over the solder 24. The photoresist layer 20 is removed by dry etching or other means (Fig. 1E). The excess UBM 18 is also removed by, for example, etching leaving a portion of the UBM overlying the contact pad 16 (Fig. 1F). Finally, the electrically conductive materials are reflown to form a solder ball or bump 28 on a semiconductor wafer 10.

[0020] In practicing the flip-chip bonding technology, it has also been found that the fatigue life of the solder ball joint is directly proportional to the height of the solder bumps (or solder balls after reflow). It is therefore desirable to increase the height of the solder balls during the fabrication process of the solder bumps and during the reflow process for the solder balls. Such increase in the height of the solder balls directly increases the fatigue life of a solder ball joint established between a flip-chip and a substrate. The present invention is directed to a method of improving the bump height.

SUMMARY OF THE INVENTION

[0021] One embodiment of the invention includes a method of making electrically conductive bumps of improved height on a semiconductor device. The method includes a step of depositing an under bump metallurgy over a semiconductor device having a contact pad thereon and a passivation layer as an upper surface of the semiconductor device and an opening formed therein down to the contact pad so that the under bump metallurgy extends into the opening of the passivation and onto the contact pad. A photoresist layer is deposited, developed and patterned over the semiconductor wafer to provide an opening over the under bump metallurgy and aligned with the contact pad. A first electrically conductive material is deposited into the opening in the photoresist layer. A second electrically conductive material is deposited over the first electrically conductive material and over a portion of the photoresist layer. Thereafter, the photoresist layer is removed, and the excess under bump metallurgy is removed leaving a portion of the under bump metallurgy overlying the contact pad and underneath the first electrically conductive material. A flux agent is applied to the top surface of the second electrically conductive material. The semiconductor device is hard baked to remove any oxide on the second electrically conductive material. Then a portion of the semiconductor devices is dipped in an electroless plating solution. The semiconductor device is removed from the electroless plating solution to provide a third electrically conductive material deposited on the second electrically conductive material. Finally, the electrically conductive materials are reflown to form a bump of improved height on the semiconductor device.

[0022] Another embodiment of the invention further includes a step of sputter cleaning